FINAL REPORT

to

DELAWARE RIVER BASIN COMMISSION

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SEDIMENTOLOGICAL AND GEOPHYSICAL SURVEY OF THE UPPER DELAWARE ESTUARY

by

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EXECUTIVE SUMMARY

This document reports the results of a sedimentological and geophysical survey of the upper Delaware Estuary, conducted during 2001–2002 by the University of Delaware (UDel) in cooperation with the Delaware River Basin Commission (DRBC). The purpose of the project was to acquire geologic data pertinent to hydrodynamic and sedimentation models implemented by DRBC to develop a Total Maximum Daily Load (TMDL) for PCBs in the Delaware Estuary. The specific objectives where as follows: (1) to develop an interpretable map of bottom sediment types in the tidal river and estuary; and (2) to quantify recent sedimentation rates at selected depositional sites within the open estuary and fringing tidal marshes. To meet these objectives, the industrialized sector of the river–estuary between Burlington, New Jersey and New Castle, Delaware was systematically surveyed using digital sidescan and chirp sonars. Sidescan sonar provided information on the horizontal distribution of bottom morphologies and sediment types, whereas chirp sonar revealed the vertical extent and continuity of subbottom sedimentary strata and bedrock. A total of 217 kilometers (350 miles) of sonar trackline were collected, covering the estuarine floor at 100 % saturation below the 5-meter isobath. To groundtruth the sonar data, sediment grain-size and porosity measurements were performed on 224 Smith-McIntyre grabs and 25 hydraulically damped cores collected in the survey area. Together, sidescan backscatter patterns and grain-size data were used to render interpretations of bottom sedimentary environment with regard to dominant sediment type and mode of transport. For three open-estuary and six marsh sites (Rancocas Creek, Woodbury Creek, Oldman's Creek, St. George's marsh, Salem River marsh, and Blackbird Creek), sediment chronologies were developed from profiles of the artificial radioisotope Cs-137 ($t_{1/2}$=30 years) to estimate recent sedimentation rates. Chronologies of the natural radioisotope Pb-210 ($t_{1/2}$=22.3 years) were developed for four of the marsh sites for comparison. In addition, sediment inventories of Cs-137 and excess Pb-210 were computed and compared to theoretical values to resolve potential pathways of suspended-particle dispersal and sequestration within the estuary and hydraulically contiguous marshes.

Bottom sediment types in the tidal river and upper estuary area span the full range of grain size, silty clay to gravel, with weight percentages that vary widely both along-

and across-channel, although across-channel variability in sand and mud content clearly increases and decreases, respectively, from DRBC Zone 3 to Zone 5. The down-estuary transition from a dominantly coarse-grained (sand and gravel) to fine-grained (clayey silt to silty clay) bottom occurs near the Zone 4–5 boundary between River Mile 75 and 85. Six general types of sedimentary environments were identified: (1) reworked bottom (three subclasses); (2) fine-grained deposition; (3) coarse-grained bedload; and (4) non-deposition or erosion. By far the most common type is the reworked bottom for which three subclasses (fine grained, mixed grained, and coarse grained) were observed. The process of bed reworking is signified by distinctive bedforms in places, corroborated by non-steady-state distributions of Cs-137 and Pb-210 downcore. Areas of coarse-grained bedload transport, characterized by sandy sediment ripples to waves, are best developed in the tidal river above Philadelphia. Areas of non-deposition or erosion, characterized by patchy bedrock exposures or a coble bottom, are confined to the Tinicum Island–Chester reach. At sites near the Rancocas River mouth and Marcus Hook shoal, an abrupt downcore change from medium-grained sand to estuarine mud was observed, suggesting that transport conditions have changed locally in recent times.

The most significant finding of this study is that fine-grained sediment accumulation within subtidal waters of the upper estuary occurs as discrete depocenters limited to the Marcus Hook–New Castle reach. Historically this segment has been the most sediment-rich of the entire Delaware Estuary and Bay, requiring nearly annual maintenance dredging by the US Army Corps of Engineers (USACE) since about 1945, when the shipping channel was uniformly deepened to 40'. Indeed, the USACE reports that >60% of the *all* the sediment dredged from the Philadelphia–Sea shipping channel is derived from the Marcus Hook–New Castle reach. At the time of the sonar surveys, fluidized mud deposits up to 1-m thick and with a cumulative mass estimated at 3.5×10^5 tons dry weight were present in the shipping channel in the vicinity of Marcus Hook alone. Presence of the short-lived radioisotope Be-7 ($t_{1/2}$=53 days) in cores from this area revealed that these deposits were emplaced rapidly in early 2001. Other fine-grained sediment depocenters were present at the mouth of the Christina River, just south of the Delaware Memorial Bridge.

In addition to its patchy distribution, fine-grained sediment deposition in the subtidal estuary is highly *discontinuous* on decadal timescales as evinced by downcore profiles Cs-137 and Pb-210. Net sedimentation rates estimated from Cs-137 profiles are ≥1 cm/yr, yet Be-7 distributions reveal that localized deposition may occur on a seasonal basis at rates approaching centimeters per month. From the sediment chronologies it is concluded that some fraction of material deposited on a seasonal basis is subsequently resuspended and dispersed such that sedimentation rates averaged over longer time spans are considerably lower. In other words, the decadal–centennial sedimentary record of the upper estuary is incomplete, as it archives only a fraction of sediment deposited on shorter timespans. This redistribution process is further evinced by sediment inventories of Cs-137, which are merely 10–14% of the expected post-1954 inventory, and considerably lower than those determined for the tidal marsh sites.

Based on Cs-137 and Pb-210 geochronology, sedimentation rates for the tidal marsh sites ranged from 0.3 to 1.5 cm/yr. Overall, Woodbury Creek, Oldman's Creek, and Rancocas Creek (all freshwater marshes) had the highest sedimentation rates and inventories of Cs-137 and excess Pb-210, revealing that these tributaries are important repositories for fine-grained sediments and adsorbed constituents. In particular, Woodbury Creek appears to be particularly efficient in sequestering suspended matter derived from its watershed, as well as material transported from the open estuary. Detailed studies of sediment transport and deposition within these and other tidal marshes are needed to illuminate their role as sediment sources and (or) sinks in the greater Delaware River-Estuary system.

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